DOCUMENT RESUME

ED 072 630 EM 010 717

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TITLE	Computer-Assisted Instruction in Undergraduate Organic Chemistry: Design, Application, and Evaluation. Technical Report 10.
INSTITUTION	Texas Univ., Austin. Computer-Assisted Instruction Lab.
SPONS AGENCY	National Science Foundation, Washington, D.C.
REPORT NO	TM-10
PUB DATE	Aug 71
NOTE	11p.
EDRS PRICE	MF-$0.65 HC-$3.29
DESCRIPTORS	*Chemistry Instruction; *Computer Assisted Instruction; Experimental Programs; Higher Education; Instructional Design; *Organic Chemistry; *Program Evaluation; *Undergraduate Study
IDENTIFIERS	University of Texas at Austin

ABSTRACT

The computer-assisted instruction (CAI) program in undergraduate organic chemistry at the University of Texas was evaluated by an experimental design in 1969 and found to be successful. This report discusses in detail the formation of the design, its application, and the method of evaluation. The program itself included 15 teaching modules that dealt with a variety of organic chemistry topics. (MC)

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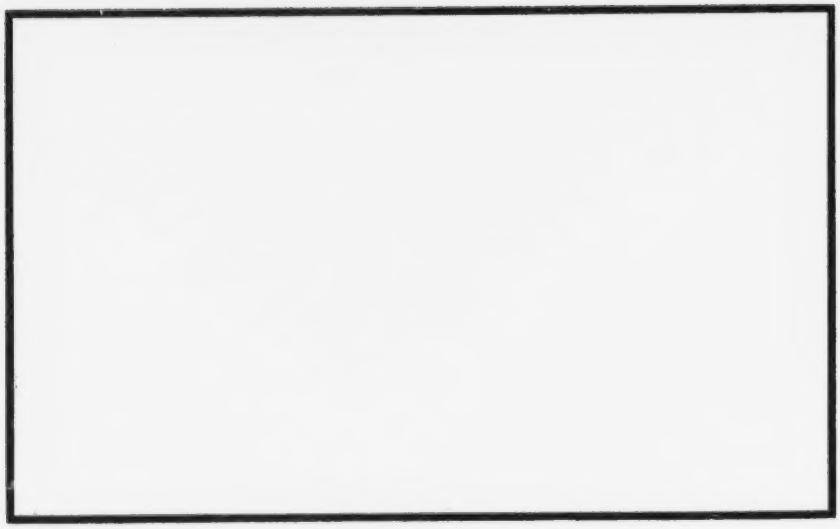

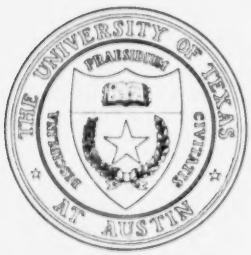

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COMPUTER-ASSISTED INSTRUCTION IN UNDERGRADUATE ORGANIC CHEMISTRY: DESIGN, APPLICATION, AND EVALUATION

TECHNICAL REPORT NO. 10

George Culp

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August 1971

Supported By:

THE NATIONAL SCIENCE FOUNDATION
Grant GJ 509 X

The University of Texas at Austin
Computer-Assisted Instruction Laboratory
C. Victor Bunderson, Director
Austin, Texas 78712

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Introduction

Computer techniques applied to instructional processes have for some time been recognized as a valuable educational tool. In the early part of the decade of the Sixties, initial efforts in computer-assisted instruction (CAI) applications were made in such disciplines as mathematics and physics. Since then, increased research efforts have characterized this mode of instructional aid.

In 1965 Lagowski and co-workers at The University of Texas at Austin first began the development of several short computer programs that were primarily of chemistry laboratory simulation. In the following two years, workers at the University of Illinois, University of Maryland, and Florida State University also opened developmental efforts of short, simulation-type CAI programs. It was not until 1968, however, that CAI programs in undergraduate chemistry were evaluated under carefully controlled conditions and in an educational environment. The studies were conducted under the direction of Professor J. J. Lagowski at The University of Texas at Austin by Castleberry (1970) and Culp (1970).

A description is presented here of two related follow-up studies to the original experiment using computer techniques in undergraduate organic chemistry instruction.

Design

The original CAI modules were:

1. Structure and Geometry of Alkanes.
2. Skeletal Isomerism of Alkanes and Stereoisomerism of Cycloalkanes.
3. Nomenclature: Alkanes and Cycloalkanes.
4. Preparations of Alkanes.
5. The Chlorination of Ethane: Mechanism.
6. The Halogenation of Alkanes: Relative Reactivities and Stabilities.

7. Stereochemistry Fundamentals.

8. Alkene-related Syntheses.

9. Electrophilic Aromatic Substitution-related Syntheses.

These modules were increased to include:

10. Preparations of Alkenes.

11. Reactions of Alkenes.

12. Preparations and Reactions of Arenes.

13. Alcohols: Reactions and Syntheses.

In addition, two more modules were developed, but they lack full-scale evaluation at this date:

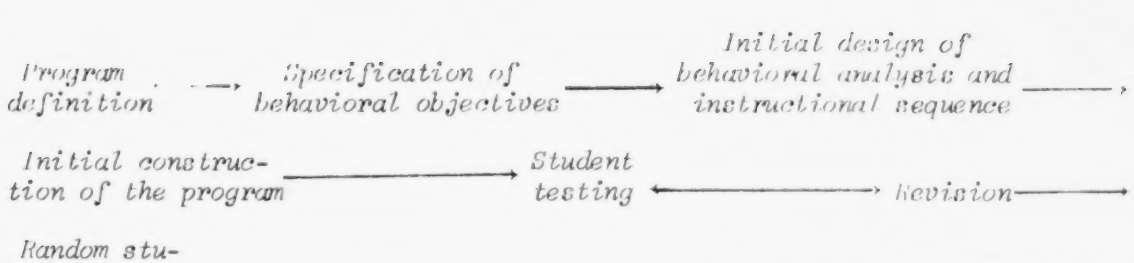
14. Elementary NMR Interpretations.

15. Elementary Organic Qualitative Analysis.

The philosophy underlying the development of these modules is the belief that, as with any discipline, there are certain concepts in organic chemistry in which the responsibility for learning is placed primarily upon the student in a self-instructional mode. These areas, for the most part, do not require the presence of an instructor but, nonetheless, are critical for the attainment of mastery of the discipline. It is also true that often the logistics of time and student enrollment number shift the responsibility of necessary drill, practice, and tutorial tasks from the instructor directly to the student. Again, the burden of responsibility weighs heavily upon the student.

Thus the modules are an attempt to utilize programs developed for CAI in hopes of supplying the needed drill, practice, and tutorial aid for certain of the areas studied in organic chemistry. In essence, the entire program is one in which a number of students, limited only by time and the availability of CAI facilities, will have the opportunity to converse with persons knowledgeable in organic chemistry via high-speed electronic computers. The task of responsibility for supplying this needed tutorial drill and practice to the student is thus placed within the command of a knowledgeable person and his guiding influence.

Essentially, each of the modules was designed following a modification of the pattern described by Lange (1967):



The modular content design is consistent with Skinner's operant conditioning:

Stimulus ⟶ *Response* ⟶ *Reinforcement* ⟶ *Stimulus*

and the design, in most cases, also parallels Gagné's (1965) Hierarchy of Learning Tasks:

Response learning ⟶ *Associations* ⟶ *Multiple discriminations* ⟶ *Behavior chaining* ⟶

Class concepts ⟶ *Principles*

Several of the modules were designed so that a student may ask for aid, repeat a question, transfer to other areas, or stop the interaction as he so chooses. The average duration of each of the modules is approximately 30-45 minutes.

Application

The application of the modules toward student utilization primarily asks the following questions:

1. Can such a program effectively supply needed drill, practice, and tutorial assistance for the student?

2. Can such a program yield evidence that it is beneficial to the student?

3. Which of the areas in the program appear to be most effectively applicable to student utilization?

4. Will the student willingly participate in the program?

5. What attitudes will a student develop toward such a program?

Experimental Design

In anticipation of gaining insights toward these questions, an experimental design was employed. The 1969 fall semester class of Chemistry 810a at The University of Texas at Austin, composed of students majoring in pre-med, pre-dental, science other than chemistry, etc., was divided by random selection into two groups of 50 students each.

The *experimental group*, in addition to their normal class activities of three 50-minute lecture sessions and one 4-hour laboratory session per week, were given access to the CAI modules for interaction at their convenience (within the schedule limitation of MWF 6-10 p.m. and TT 1-4 p.m.). The *control group* participated only in the conventional class activities. Comparison of groups was between experimental group CAI users, experimental group CAI non-users, and the control group.

The 1970 spring semester class of Chemistry 818a, composed of students majoring in chemistry or chemical engineering, was divided by laboratory section into the following four groups:

(1) *CAI users*, who were required to interact at least one hour per week with the computer modules.

(2) and (3) *TA1* (teaching assistant) and *TA2*, who were required to meet for one 50-minute session per week with their respective TAs for tutorial drill similar to that provided by the CAI modules, plus question and answer sessions as questions may arise on other topics.

(4) *Control*, who participated only in the conventional activities of the class (similar to those described above for Chemistry 810a).

Comparison of groups was between CAI users, combined participants of the TA sessions, and the control group.

Evaluation

Method

For the 1969 fall semester class of Chemistry 810a, the method of evaluation was based upon a statistical t test analysis of the means of items on examinations that were either directly related or unrelated to the material presented in the CAI modules. The means of the Experimental Group CAI Users, Experimental Group CAI Non-Users, and the Control Group were compared.

For the 1970 spring semester class of Chemistry 818a, a statistical t test was again employed to test for differences on items of direct,

indirect, and no relationship to the material in the CAI modules between the CAI, TA, and Control Groups. In addition, a comparison of subjective student attitudes was performed between the CAI and TA groups.

Results:

The results of examination score performances, which are listed in Table 1, for the Chemistry 810a class on items of direct and no relationship to the CAI material indicate that CAI exerts a positive influence on score performance. The Experimental Group CAI Users scored consistently and significantly higher than the Experimental Group CAI Non-Users on five of five examinations, including the final examination, and on three of five examinations, including the final examination, when compared with the Control Group. A statistically significant difference in favor of the CAI group for unrelated items, however, occurs only on two of five examinations when compared with the Experimental Group CAI Non-Users, and only on one of five examinations when compared with the Control Group. The semester average of performances on related items, after conversion to a 100-point basis, also indicates a statistically significant difference in favor of the CAI Users over Experimental and Control Group Non-Users of CAI. A significant difference is absent, however, for unrelated items. The average terminal sign-on time was 6.20 hours per student.

Positive influence of CAI participation on score performances is also exhibited by the results of examinations for the Chemistry 818a class. These effects appear in Table 2. The CAI group scored consistently and significantly higher than the TA and Control Groups on items of direct relationship to CAI/TA interactions on all examinations, excluding Hour Exam I and the Final Examination. The former results are no doubt explained by the fact that a lengthy quiz that included coverage of all CAI-related items was given one week prior to Exam I. The CAI group did show a significant difference from the other groups on related items for this quiz. The results of the final examination are more difficult to account for, but may partly reside in the stronger background ability of the Control Group, as indicated by their SAT verbal and quantitative scores. As with the 810a class, the semester mean of related items following conversion to a 100-point basis indicates a significant difference in favor of the CAI group, whereas no difference exists for unrelated items. Additional support for CAI is shown in Table 3. The students in the CAI group consistently indicated a greater positive opinion for CAI-type assistance over teaching assistants. This probably reflects the varying abilities of the TAs and the influence of individualized instruction exhibited by CAI.

The areas of Nomenclature, Organic Reactions, and, in particular, Organic Syntheses, consistently proved to be the areas most effectively suited to CAI utilization, not only in score performances, but also student preference. The average terminal sign-on time was 11.20 hours per student.

Table 1

Mean Score Performances for Examination Items Related and Unrelated to the CAI Modules

Chemistry 810a, Fall 1969

Related items					*Unrelated items*				
Exam	Point Value	Group	$\bar{X}$	N	Exam	Point Value	Group	$\bar{X}$	N
		CAI	57.56[2]	39			CAI	20.26	39
I	76	Cont	54.89	47	I	24	Cont	20.17	47
		NU*	49.27	15			NU*	19.40	15
		CAI	42.21[1,2]	24			CAI	31.00	24
II	62	Cont	37.72[2]	47	II	38	Cont	29.85	47
		NU	29.53	30			NU	27.73	30
		CAI	24.00[1,2]	26			CAI	46.96[2]	26
III	30	Cont	21.68[2]	41	III	70	Cont	43.61[2]	41
		NU	18.19	16			NU	37.00	16
		CAI	10.79[2]	14			CAI	65.64[1,2]	14
IV	15	Cont	10.47[2]	38	IV	85	Cont	59.37[2]	38
		NU	7.74	31			NU	50.35	31
		CAI	118.59[1,2]	22			CAI	85.36	22
Final	189	Cont	108.40[2]	40	Final	111	Cont	83.70	40
		NU	94.77	13			NU	79.69	13
		CAI	71.70[1,2]	22			CAI	77.44[2]	22
Sem.	100	Cont	66.50[2]	40	Sem.	100	Cont	74.03[2]	40
Ave.		NU	54.97	13	Ave.		NU	67.50	13

Average terminal time: 6.20 hours/semester/student

*Students in the experimental group but who were Non-Users of CAI materials

[1]Statistically significant difference from Control Group

[2]Statistically significant difference from Non-User Group

Table 2

Mean Score Performances for Chemistry 818a Groups

Chemistry 818a, Spring 1970

Mean Background Ability

Group	SAT Verbal	SAT Quantitative	Chemistry Placement
CAI	555	629	36.4
TA	548	621	32.8
Control	563	656	35.3

Examination Performance

		Related items				*Indirectly related items*				*Unrelated items*			
Exam	Point Value	Group	$\bar{X}$	N	Point Value	Group	$\bar{X}$	N	Point Value	Group	$\bar{X}$	N
		CAI	53.70[1]	20	--	--	--	--		CAI	22.70	20
Q.1	66	TA	44.46	24	--	--	--	--	34	TA	22.58	24
		Cont	44.12	40	--	--	--	--		Cont	22.09	40
		CAI	24.96	24	--	--	--	--		CAI	54.48	24
I*	36	TA	24.50	24	--	--	--	--	89	TA	57.03	24
		Cont	25.07	40	--	--	--	--		Cont	57.04	40
		CAI	30.05[1]	20		CAI	26.60	20		CAI	16.61	20
II	48	TA	24.88	20	48	TA	29.20	20	39	TA	17.38	20
		Cont	25.85	34		Cont	26.20	34		Cont	15.38	34
		CAI	15.89[1]	20		CAI	23.10	20		CAI	22.20	20
III	30	TA	9.41	17	38	TA	22.35	17	112	TA	26.41	17
		Cont	11.19	31		Cont	22.26	31		Cont	25.35	31
		CAI	42.22	18		CAI	67.27	18		CAI	52.73	18
Final	97	TA	42.44	18	120	TA	61.28	18	157	TA	50.45	18
		Cont	41.60	30		Cont	67.07	30		Cont	63.03[1]	30
Sem.		CAI	63.56[1]	18		CAI	57.42	18		CAI	44.38	18
Ave.	100	TA	54.07	18	100	TA	56.91	18	100	TA	45.72	18
		Cont	55.74	30		Cont	56.35	30		Cont	45.81	30

Average terminal time: 11.22 hours/semester/student

*Related items, and some unrelated items, were presented on Quiz 1, one week prior to Exam I.

[1]Statistically significant difference from group with next highest mean.

Table 3

Student Opinion and Attitude by Group

Chemistry 818a, Spring 1970

Opinion Criterion	CAI Students Agree	TA Students Agree
1. The time required was of value.	81%	58%
2. Participation in the group was a definite aid to learning.	95%	50%
3. Optional participation in the group should be continued.	100%	83%
4. Participation in the group was enjoyable.	86%	33%
5. For any future studies, I prefer assignment to my current group.	77%	46%

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